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Slip, Twins and Voids: The Micromechanics of Anisotropic Ductile Damage

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ABSTRACT:

Magnesium (Mg) and its alloys are candidates for many advanced engineering applications because of their low density, good stiffness and strength. However, their wide-spread insertion as preferred structural materials is stymied by the limited knowledge on designing damage tolerant microstructures. The remarkable crystallographic plastic anisotropy, tension-compression asymmetry and strong texture effects are often referred to as origins of damage intolerance in these low symmetry, hexagonal close packed (HCP) materials. While post-mortem experimental evidences indicate ductile processes at play, the role of anisotropic slip and twinning mechanisms on the rates and states of damage accumulation remains elusive. Moreover, a theory that systematically connects the deformation mechanisms to the mechanics of anisotropic damage, is currently not available. Developing such a theory is imperative for designing tougher Mg alloys. We present the micromechanics of intragranular ductile damage by void growth and coalescence in Mg under triaxial stress states. Using a finite deformation HCP crystal plasticity framework within three-dimensional finite element calculations, we map the crystallographic aspects of anisotropic void growth that emerge from rich interactions with slip and twinning mechanisms, leading to complex coalescence characteristics. Integral to our investigation is the prediction of the onset of void coalescence, providing insight into the micromechanics of material instabilities in such highly anisotropic materials. On a broader note, the present research serves as a step towards developing crystallographically informed theory of anisotropic continuum damage mechanics for predictive ductile failure of advanced materials.

BIOGRAPHY:

Shailendra Joshi is an associate professor in the Department of Mechanical Engineering at National University of Singapore (NUS). Prior to joining NUS, he was a post-doctoral fellow in the Department of Mechanical Engineering at the Johns Hopkins University (2005-2008). He earned his PhD in Civil Engineering from Indian Institute of Technology Bombay in 2002. After a short stint as a visiting scientist at the University of Stuttgart, he joined GE-India Technology Center in Bangalore (2003-2005). His research focuses on understanding strengthening and failure processes in novel materials through computational and experimental mechanics with an interest in designing lightweight materials with enhanced mechanical behaviors. He serves on the Editorial Board of Materials Science and Engineering-A, an Elsevier Journal.